Bell Laboratories **RECORD**

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Cover

Magnetic yttrium iron garnet crystals spill out of platinum crucible in which they were synthesized. X-ray photographs yield film strips from which graphs and structural models can be made. Natural garnet in foreground serves as pedestal for Garnet Rose.
(See story on page 81)

Tracking and Communications Network Vital To Glenn's Orbital Flight

America's biggest day in space—last month's three-orbit flight by John Glenn—was made possible by the National Aeronautics and Space Administration industrial team that included Western Electric and Bell Telephone Laboratories. After the successful launching, flight, and recovery of Colonel Glenn, NASA officials reported that "tracking and telemetry were beautiful" and that "plot boards showed the smoothest tracking" of any Project Mercury mission.

The vast 18-station tracking and communications network was built for NASA by five companies which were led by the Western Electric Company. Bell Laboratories served as consultant on all technical phases of the project and was responsible for systems analysis and test planning. In addition, the Laboratories supervised the design of the Mercury Command and Control Center at Cape Canaveral and developed a simulator for training the Mercury flight controllers (RECORD, *October*, 1961).

The tracking and instrumentation system followed Glenn with radar and collected and transmitted telemetry data covering nearly 100 items, including environment in the capsule and the astronaut's physiological condition. This information was funneled into the Goddard Space Flight Center at Greenbelt, Maryland, the computer and communications hub of the entire network. Here high-speed computers and switching equipment organized and relayed this information to the Mercury Control Center.

Cape Canaveral is the focal point for all the information gathered by the stations in the tracking network. Sixteen of the eighteen stations serve as collection points for data on the condition of the astronaut and the capsule. Six of the ground stations are also equipped to control certain flight operations or events within the capsule.

The tracking and information system offers essentially continuous, two-way radio contact with the orbiting capsule; for talking with the astronaut, for receiving telemetry of instrument readings in his spacecraft and for controlling remotely certain flight equipment in the capsule. These radio links use one channel in the HF range between 15 and 30 megacycles and three in the UHF range of 200 to 300 megacycles.

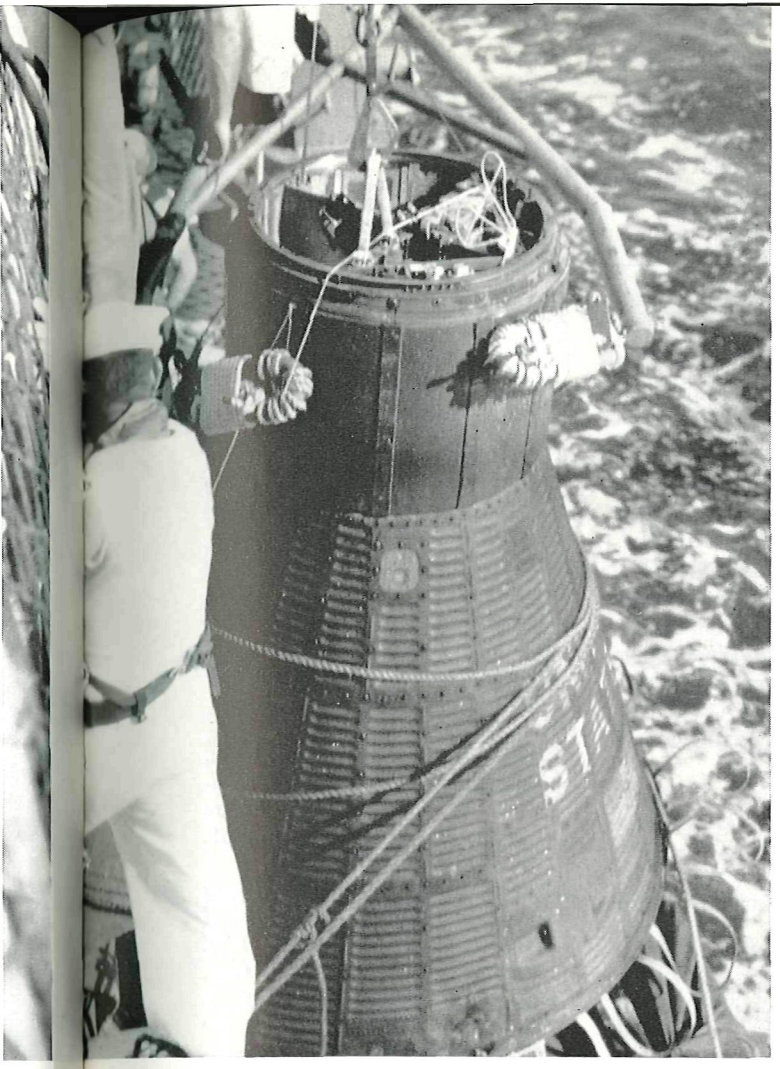
The system also has a world-girdling network of communication circuits for voice, teletype and data transmission between stations. Leased facilities of communications carriers in many lands are used as well as a wide variety of communication techniques. These facilities include land lines, submarine cables, microwave and HF point-to-point radio systems and both wire and radio carrier arrangements.

Extent of Communications Network

Altogether the communication facilities comprise some 35,000 miles of voice channels interconnecting 13 sites; 96,400 circuit miles of teletype channels connecting all sites (this circuit also transmits radar data from 13 sites); and 5,500 circuit miles of high-speed data transmission channels between Canaveral and Goddard Space Flight Center. A significant achievement of the Laboratories engineering effort was the development of a system that handled vast amounts of data, generated at points sometimes separated by the entire world, in essentially "real time"; that is, nearly instantaneously.

The Mercury capsule is tracked by radar for the entire period of *powered* flight and as it passes within range of radars at eleven of the sites. Radar data flows by automatic teletype connection directly into electronic computers at Goddard. The computers maintain a continuous "estimate of present position" of the spacecraft and predict when and where it will arrive for succeeding sites. These "acquisition messages" are originated by the computer and are teletyped automatically to remote sites.

Approximately 37 quantities vital to the success of the mission are derived from the computers and transmitted over high-speed data channels



Friendship 7, the Mercury capsule which carried astronaut John Glenn during this country's first manned orbital flight is lifted to deck of USS Noa during recovery operation. (U. S. Navy photo from UPI)

for display in the control center at Canaveral. The many complex programs that the computer uses to analyze and predict the position and condition of the capsule are selected and controlled automatically by a "monitor," or master program, which maintains order within the computer, recognizes the apparent situation and arranges the computer activities to fit appropriately into the time sequence of the flight.

Control Center Arrangements

The Command and Control Center at Cape Canaveral has 14 control consoles, 37 computer-operated displays, uses four duplex 4-wire voice channels to the network, has six full duplex teletype channels to the network, and displays or records approximately 100 telemetered quantities from the capsule.

A supplementary control center at the Bermuda tracking site can control the capsule's insertion into orbit if the Canaveral control is weak. The Bermuda control center has seven operating consoles, access to four, full-duplex teletype channels, and two channels to the world voice network. It is served by two radars, a computer, telemetry, and command control equipment.

To give the NASA flight controllers the specialized training needed to conduct Mercury missions, Bell Laboratories designed an elaborate training simulator that activates the Goddard computer just as though a real mission were taking place.

From the simulation room, located in another part of the control center building, all displays in the control room can be realistically operated. For example, the displays that would normally be activated by telemetry data can be operated either with tape recordings or by controls on an instructor's panel. The decisions that the flight controllers make during these simulation tests can be realistically followed by appropriate indications from the computer, so that the machines as well as the men can be exercised.

In an actual training exercise, a tape recording of an Atlas launch is played over the connections to Goddard, starting the computers into their launch computations. The computers, in turn, send back their indications to the control center. The flight controllers response to these indications are followed by realistic displays on the various meters and dials on the control consoles and other control displays. This is called "closed-loop" simulation.

To insure reliability in the high-speed data circuits between Canaveral and Goddard, two transmission paths on separate wires are used in each direction. Only one of these paths need operate for reliable transmission. If both the original paths fail, a similar pair of paths are provided by an entirely different route.

In the ground communications network, duplicate communication channels are provided to all critical stations. Alternate routes are provided as standbys in the critical paths. Acquisition messages are transmitted to each site three times, approximately twenty minutes apart, to minimize the possible effects of radio path "drop-outs." These were not the only precautionary measures. In addition, every feasible principle of operational integrity, human factors, and safety was engineered into this pioneer tracking and communication network for America's first experiments in manned space exploration.